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Inventor: Tsujimoto Yutaka
Applicant: Kubota Corporation

(54) [Name of the Invention] Composite Roll

(57) [Abstract] To facilitate the crystallization of graphite and to prevent the generation of casting cracking in the process of the production as to a graphite crystallized high-speed steel series cast iron material sued as the external layer material of a composite roll for rolling.

[Claimed ranges]

[Claim 1]

A high speed steel type cast iron containing graphite with the following composition range (by wt %):

C: 1.8—3.6%, Si: 1.0—3.5%, Mn: 0.1—2.0%, Ni: 0.5—10.0%,
Cr:1.5—10.0%, Mo: 0.1—10.0%, W: 0.1—10%, a total 1.0-10.0% of one or two from V and Nb, O <100ppm, N<300 ppm, the rest is Fe.

[Claim 2] The above high speed steel type cast iron in Claim 1 containing 0.5-10.0 % cobalt.

[Claim 3] The above high speed steel type cast iron in Claim 1 and 2 containing one or two kinds from 0.01-0.5% Al, 0.01-2.0% Ti, 0.01-2.0% Zr.

[Claim 4] The above high speed steel type cast iron in Claims 1-3 containing 0.01-0.5% B.

[0001]

[Detailed Description of the Invention] The present invention is about graphite containing high speed steel type cast iron used as external layer material for composite roll.

[0002]

[Prior Art] Japan patent 6-256889 discloses graphite containing high speed steel type cast iron for external layer of composite roll. The cast iron contains graphite and alloy carbides (MC, M_7C_3, M_6C, M_2C etc.) in its microstructure. The graphite provides a lower frictional coefficient and good thermal conductivity while the alloy carbides give excellent wear resistance to the alloy.

[0003]

[Problems to be solved in the Invention]

It is necessary to have Cr, Mo, W, V, Nb in order to achieve excellent wear resistance of the external layer material of composite roll. Unfortunately, these carbide formers will restrict graphite formation. Silicon is effective in promoting graphite formation, however, higher silicon content increases crack tendency when the roll cools. The purpose of the invention is to promote graphite formation without increasing silicon content.

[0004]

[Methods used in the Invention] In order to achieve the above goal, it is found in the present

invention that lower down O and N content can promote graphite formation, specifically speaking, this is de-oxygen and de-nitrogen treatment to lower down oxygen less than 100 ppm and nitrogen less than 300 ppm. The composition of the graphite containing high speed steel type cast iron is given as by weight percent;

C: 1.8—3.6%, Si: 1.0—3.5%, Mn: 0.1—2.0%, Ni: 0.5—10.0%,

Cr: 1.5—10.0%, Mo: 0.1—10.0%, W: 0.1—10% a total of 1.0-10.0% from V and/or Nb, O <100ppm, N<300 ppm, the rest is iron.

[0005] In the present invention cobalt can also be added by 0.5-10.0% to the alloy if needed, and one or two from 0.01-0.5% Al, 0.01-0.5% Ti, 0.01-2.0% Zr can also be added to the alloy of necessary, furthermore the alloy also contains 0.01-0.50% B.

[0006] O and N can stabilize carbides. Lowering oxygen and nitrogen content can limit carbide growth and promote graphite formation. Moreover, non-metallic inclusions formed by oxygen and nitrogen will deteriorate toughness of material and increase casting crack tendency. The lower the oxygen and nitrogen content the lower the casting crack tendency.

[007]

[Reasons for the chemical composition]

C primarily combines with Fe and Cr to form M_7C_3 complex type carbide, and will also form MC, M_6C, and M_2C type high hardness complex carbides when combining with Cr, Mo, V, Nb, and W. combines with Mo, V, Nb, and W alloy elements. When carbon is less than 1.8 wt %, there is only a small amount of carbides and no graphite formed in the alloy; when carbon is greater than 3.6 wt % there will be too much carbides and graphite to increase the brittleness of the roll material.

[008] Silicon is the necessary element to ensure good fluidity and precipitation of graphite. Silicon has a less effect when its content is less than 1.0 wt % while deteriorating wear resistance of the roll material when silicon is higher than 3.5 wt % to have graphite area greater than 7% because graphite will become the starting point of wear loss. On the other hand inoculation can be more effective in promoting graphite precipitation when silicon is added before poring.

[009] Mn can increase the hardness of the alloy. Moreover, Mn will combine with S to form MnS, which is the necessary element to prevent material brittleness caused by sulfur. Raw material contains about 0.1 wt% Mn, however when Mn is higher than 2.0 wt % it will decrease the toughness of the alloy.

[0010] Ni: 0.5-10.0%

The purposes of adding Ni are to improve matrix property and also promote graphite precipitation. There will be not enough graphite formed if nickel is less than 0.5 wt % and, similar to the effect of silicon, too much graphite will be formed when nickel is higher than 10.0 wt %. Higher nickel content will also increase the amount of residual austenite, which will deteriorate wear resistance even after heat treatment.

[0011]

Cr: 1.5-10.0%

Together with Fe, Mo, V, and Nb, Cr can combine with carbon to form complex high hardness carbides to increase high temperature wear resistance. Cr in solid solution can improve hardening ability in quenching operation to enhance wear resistance. There is no obvious benefit when Cr is less than 2.0 wt % however, Cr will worsen toughness when higher than 10.0 wt %.

[0012] Mo: 0.1-10.0%

Similar to Fe, Cr, V, Nb, and W, Mo can easily form M_7C_3, M_6C, and M_2C type carbides to increase room and high temperature hardness and also wear resistance. There is no obvious effect when the amount of Mo is less than 0.1 wt % while deteriorating toughness when the amount is higher than 10.0 wt %.

[0013] W: 0.1-10.0%

Similar to Fe, Cr, Mo, V, and Nb, W can easily form complex carbides to increase room and high temperature hardness and also wear resistance. There is no desired improvement in wear resistance when the amount of W is less than 1.5 wt % wt % while deteriorating toughness and also resistance to hot cracking when the amount is higher than 10.0 wt %. On the other hand, W has a high tendency to segregate during centrifugal casting process, therefore, W should be controlled under 10.0 wt %.

[0014]

V and Nb: 1.5-10.0 wt % of the one or two.

Similar to Fe, Cr, Mo, and W, V and Nb can easily combine with carbon to form MC type carbides to increase room and high temperature hardness and also wear resistance. Furthermore, dendrite from MC type complex carbide grows along depth direction to resist matrix deformation, which is benefit to mechanical properties, especially resistance to cracking. V and/or Nb is not effective when the amount is less than 1.5 wt % while deteriorating toughness when the amount is higher than 10.0 wt %. V and Nb will also segregate during centrifugal casting process if the amount is too high.

[0015] O: less than 100 ppm

Oxygen can stabilize carbide and increase the amount of carbide, oxygen can also make it difficult for graphite to precipitate from matrix. On the other hand, oxygen forms non-metallic inclusions to decrease the purity of the alloy. Too much oxygen will cause casting cracks. In the present invention a proper de-gassing process is used to decrease oxygen content to be lower than 100 ppm, hopefully lower than 80 ppm, and the best to be less than 40 ppm.

[0016] N: less than 300 ppm,

Nitrogen forms non-metallic inclusions to decrease the purity of alloy. Too much nitrogen also cause casting cracks. In the present invention, a degassing process is used to reduce nitrogen content to be less than 300 ppm, hopefully less than 250 ppm, and the best to be less than 130 ppm.

[0017] Co: 0.5-10.0%

Co has a strong effect to improve the matrix property. Co also has a special effect to retard the carbon diffusion and also increase toughness through solid solution in the matrix. Cobalt improves high temperature hardness and wear resistance. Furthermore, cobalt can increase the solubility of carbide forming elements in austenite, resulting in a higher matrix hardness and better oxidation resistance. Cobalt content needs to be greater than 0.5 wt% to achieve these effects, but no further improvement if cobalt is greater than 10.0 wt % plus cobalt is a very expensive element. Higher cobalt content will also cause uneven carbide distribution during centrifugal casting process. Therefore cobalt should be controlled between 0.5-10.0 wt %.

[0018] Al: 0。01—0。5%, Ti : 0。01--2。0%, Zr : 0.01—2。0%

In the present invention, it is necessary to add one or two kinds from Al, Ti, and Zr. Al, Ti, and Zr can reduce oxygen content in the melt metal by forming oxides to improve product quality. Meanwhile the formed oxides can act as crystal nuclei to refine microstructure: There will be residual inclusion left in the alloy if added too much. The purpose of adding Al, Ti, and Zr is mainly to refine microstructure to improve its wear resistance besides the degassing effect. Therefore the content of these elements in the alloy should be controlled to 0.01-0.5% Al, 0.01-2.0%, 0.01-2.0% Zr.

[0019] B: 0.01—0.50%

B can be added to the inventive alloy if needed, B has the degassing effect by combining with oxygen in the melt alloy. The formed oxides can also have the effect of crystal nuclei during solidification to refine microstructure as well as the effect to improving fluidity. B in the matrix can improve oxidation resistance of the alloy. In large castings like cast iron rolls, it is still easy to obtain quenched microstructure because of improvement in hardening ability though it is difficult to achieve fast cooling in large castings. No obvious effect if B is less than 0.01 wt % while material becomes brittleness when B is higher than 0.5 wt %.

[0020] Besides the above alloy elements in the present invention, the balance is iron and other inevitably impurities, such as P and S from raw materials. These two elements should be controlled to the minimum level to avoid increase brittleness of the alloy. P should be less than 0.2 % and S less than 0.1%.

[0021]

[Actual examples]

The high speed steel type cast iron in the present invention is melt under atmosphere, a certain amount of de-gassing elements are added to reduce oxygen and nitrogen content in the liquid metal by forming oxides and nitrides. Elements used for reducing oxygen are Si, Mn, Al, Ti, Zr, B, and Ca as well as their compounds. When Ca is used to degassing, there is hardly any Ca left in the castings because Ca oxides will be removed as slag during melting.

[0022]

The present invention is used as the external layer material in the composite roll. The composite roll is formed by metallurgically bonding the inner surface of the external layer and the inner roll,

or using an intermediate layer to form a three-layer composite roll. The inner material can be advanced grey iron, ductile iron, graphite steel, and casting steels or other materials with high toughness. The intermediate layer material is Adamite. After centrifugal casting the external and intermediate layer, if needed, the inner layer is cast statically. The external layer of shell type castings can be made by centrifugal casting process. After casting the external layer or the required intermediate layer, the solid inner layer is then poured statically. There are three types of centrifugal casting methods according to the shell shaped mold axis direction, vertical, horizontal, and angled. Each method is suitable to make composite roll.

[0023]

The graphite containing high speed steel type cast iron roll in the present invention can be heat treated, for example, cool the roll from austenizing temperature to 400-650 C to achieve excellent quenching microstructure to achieve good quenching microstructure, followed by one or more tempering treatment.

[0024]

[Actual example] Use high frequent induction furnace to melt various alloys as shown in table 1. Use centrifugal casting process to make a shell casting for the test. The speed of the centrifugal process is 140 rpm. The pouring temperature is 1300 C, and the dimensions of the casting are 318 mm in out diameter, 238 mm in inner diameter, and 550 mm in length.

[0025] In Table 1, No.1 is the example without degassing. No. 2 and No. 3 are examples with 0.05 wt% ferro-titanium (Fe-Ti). No. 4 is an example with 0.05 wt% Al besides Fe-Ti to remove oxygen. No. 5 is an example with B and Fe-Ti to remove oxygen. All titanium has been consumed to oxides and nitrides, therefore there is no titanium in the final casting when titanium is 0.05 wt%.

[0026] Make metallographic samples from each sample alloy, observe microstructure of these samples and measure precipitated graphite. The results are listed in Table 1.

[0027]

[0028] It is clear from table 1 that graphite precipitation increases when oxygen level is low compared with samples containing similar amount of silicon. Once the oxygen is below 40 ppm, the precipitated graphite can reach 3.8 %

[0029] After casting all alloy samples, take these castings from permanent molds to exam for any defects. There is a crack along shell axis direction. The crack can be removed in machining operation because the crack is shallow. There is no crack found in No. 2-5. This confirms that castings become crack sensitive when nitrogen content is too high.

[0030]

[Benefits of the Invention] The present invention of graphite containing high speed steel type cast iron can be used as external layer material for composite roll, which is suitable for hot or cold rolling rolls. It is not easy to form crack during manufacturing process because of the precipitated graphite.